(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 111 081 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
27.06.2001 Bulletin 2001/26

(51) Int Cl.7: C22C 38/12, C22C 38/14

(21) Application number: 99870278.1

(22) Date of filing: 22.12.1999

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: SIDMAR N.V.
B-9042 Gent (BE)

(72) Inventors:
- Vandeputte, Sven
2870 Ruisbroek (BE)
- Claessens, Serge
2100 Deurne (BE)

(74) Representative: Van Malderen, Joelle et al
Office Van Malderen,
Place Reine Fabiola 6/1
1083 Bruxelles (BE)

(54) **An ultra-low carbon steel composition, the process of production of an ULC BH steel product and the product obtained**

(57) The present invention describes an ultralow carbon bake hardenable galvanised or galvannealed steel product, having a higher yield strength at the temperature of the molten zinc bath while maintaining a low yield strength and excellent bake hardening properties in a skinpassed condition, BH_0 being higher than 35MPa and BH2 higher than 40MPa (GI) and BH_0 > 20MPa and BH_2 > 30MPa (GA), as well as having a superior paint appearance after stamping and painting. The content in the steel composition of the Ti is comprised between 3,42 N and 3,42 N + 60 ppm for a fixed nitrogen content (N), and the Nb-content, comprised between 50 ppm and 100 ppm, is fixed so that no substantial precipitation of niobium carbides will occur during the process.

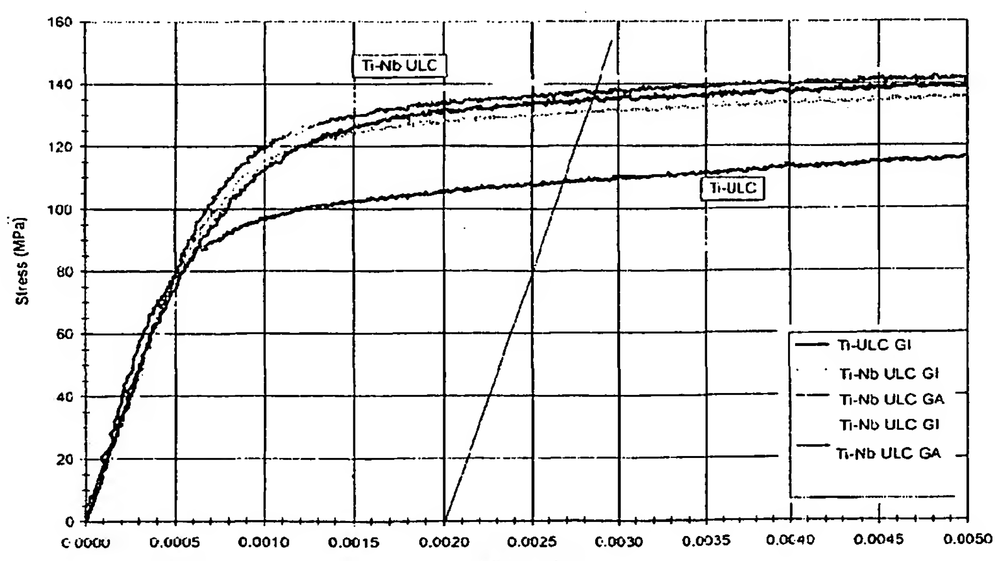

Figure 2a

EP 1 111 081 A1

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the invention

[0001] The present invention is related to an ultra-low carbon steel composition. The present invention is also related to a process of production of an ultra low carbon bake hardenable steel having said composition. The present invention is also related to the end product of said process.

Background of the invention

[0002] In the automobile industry there is a need for hot dip galvanised or galvannealed ultra-low carbon bake hardenable steel (also called ULC BH steel) having excellent dent resistance and very good paint appearance.

[0003] Several documents are describing such ULC BH products having either titanium (obtained by the so called Ti-route) or titanium-niobium (obtained by Ti/Nb-route).

[0004] More particularly, document EP-A-0064552 describes a method of producing a thin steel sheet having a high baking hardenability and adapted for drawing. The document describes a method comprising the steps of forming a molten steel having a composition containing 0.002-0.015% by weight of C; 0.04-1.5% of Mn; not more than 1.2% of Si; not more than 0.10% of P; 0.001-0.01% of N; 0.01-0.10% of Al, and Nb in an amount within the range (in %) from 2C to 8C+0.02 into a slab, hot rolling the slab, cold rolling the hot rolled sheet, subjecting the cold rolled sheet to a continuous annealing at a uniform temperature between 900°C and the Ac3 point, and cooling the annealed sheet to a temperature of not higher than 600°C at an average cooling rate of at least 1°C per second, preferably at least 10°C per second.

[0005] However drawbacks of this process are the high soaking temperature necessary to dissolve carbides and the fact that a high cooling rate after soaking is necessary to prevent reprecipitation of these carbides. Other disadvantages are the fact that beside the carbon content which must be controlled in a narrow range, also the Nb/C ratio in the steelmaking plant has to be controlled, and finally that, due to the use of Al for binding the N, high coiling temperatures are preferably used in order to prevent deterioration of mechanical and ageing properties at the coil ends in case of continuously annealed steel. Higher coiling temperatures are disadvantageous for the pickling of the hot rolled steel before cold rolling.

[0006] Document JP-10280092 describes a hot dip galvanised steel sheet having minimal age deterioration in press formability and good baking finish hardenability. This steel has a composition comprising C, Si, Mn, P, S, Al, N, Ti, Nb, Fe and if necessary B, and is providing a metallic structure in which a specific volume percentage of iron carbide exists in the ferrite grain boundary. This metallic structure is formed by subjecting a slab of steel with the above composition to finish rolling at a temperature not lower than the A_{r3} point, performing cold rolling at 65-95%, and then applying continuous hot dip galvanising and temper rolling to the resultant steel sheet under respectively controlled conditions.

[0007] However, iron carbide precipitation in such kind of ULC steels was never detected in the as produced condition due to the very low amounts of carbon and the short times during which these low amounts can precipitate in a continuous annealing process. On the other hand, segregated atomic carbon in grain boundaries has long been physically known.

No BH_0 values are mentioned. Also, according to the document, finishing rolling must be performed not lower than the A_{r3} point which becomes more difficult in case of alloying with P and Si. No minimum Nb addition is specified in the abstract. Ti is added as a function of N and S-contents.

[0008] Document JP-5059443 describes a process of fabrication of a steel sheet having good formability which comprises the steps of adding Ti and Nb in relation with the C, N, S contents, while controlling carbonitride in an ultra-low carbon steel having a specific composition where Ti and Nb are combinedly added. This steel is hot-rolled at a finishing temperature (T2) higher than or equal to (A_{r3}-100)°C, coiled at a temperature (T3) between 500 and 750°C, and cold-rolled with a reduction of area higher or equal to 60%. Subsequently, this steel sheet is subjected to recrystallization annealing at 700-850°C by means of a continuous hot-dip galvanising line having an in-line annealing furnace, and galvanising is done in the course of cooling. By this method, a hot dip galvanised cold rolled steel sheet having required baking hardenability (BH characteristic) and formability can be obtained.

[0009] However, Nb addition as a function of carbon is an extra difficulty to realise in an industrial steelmaking plant.

[0010] Document EP-A-0816524 describes a cold-rolled steel sheet or a zinc or zinc alloy layer coated steel sheet containing 0.0010 to 0.01% of C and having a steel composition containing one or two kinds of 0.005 to 0.08% of Nb and 0.01 to 0.07% of Ti in the ranges given by specific relations. However, Nb and Ti are added specifically to have a minimum amount of fine NbC and/or TiC not less than 5 ppm, in order to get higher n-values. Moreover, said document gives explicitly a range for BH_2 between 10 and 35MPa, without mentioning BH_0 values.

[0011] Prior research and industrial trial results have shown that another problem in the current state of the art is the low yield strength of existing Ti-ULC BH steels at the zinc bath temperature, which has a negative effect on the surface

appearance of such steel sheets. The bad surface appearance of steel sheet obtained through the Ti-route is a consequence of small deformations, which are caused in the zinc bath and its immediate surroundings, by the high tensile stress in the zinc bath section and by the guiding rolls, which are positioning the sheet between the air knives. In fact, the sum of the tensile stress generated by both the tensile forces applied to control the band behaviour as well as the stress induced in the outer surface layers by bending of the sheet on the rolls in the zinc bath and by the imbricator rolls, may not exceed the yield strength of the material at the elevated temperatures of the zinc bath and its surroundings. The appearance is indeed increasingly bad at higher line tensile stresses and higher out of line imbricator roll positioning.

[0012] After stamping and before painting, this effect can be visualised on a Marciniak sample by way of transversal lines, even on sheets which have undergone the skinpass treatment and have been labelled as suitable for exposed parts. After the final painting of the surface, it exhibits an orangepeel-like appearance with high waviness. Due to this phenomenon, it can be expected that steels with a low yield strength (less than 220-240MPa at room temperature) are most likely to suffer from this, which has indeed been verified in laboratory tests.

Aims of the invention

[0013] It is the aim of the present invention to provide ultra-low carbon BH steel, intended for hot dip galvanised or galvannealed BH steel applications, requiring excellent formability, with excellent paint appearance after panel forming and painting in addition to excellent dent resistance after paint baking.

[0014] A further aim of the present invention is to provide a steel having a higher yield strength at the zinc bath temperature.

Summary of the invention

[0015] The present invention is related to an ultra-low carbon steel composition intended to be treated in a process comprising the steps from hot-rolling until hot-dip galvanising or galvannealing and skinpass, said composition being characterised by the content of titanium, which is comprised between 3.42N and 3.42N+60ppm for a fixed nitrogen content (N) and by the niobium content, which is comprised between 50 and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur during said process. More specifically, the present invention relates to an ultra-low carbon steel composition with the above characteristics, wherein no more than 2ppm of carbon is bound in the form of Nb-carbides during said process

[0016] The composition of such an ultra-low carbon bake hardenable steel product is preferably characterised by

- a C-content comprised between 15ppm and 45ppm,
- a N-content comprised between 0 and 100ppm, preferably between 0 and 40ppm,
- an Al-content comprised between 0 and 1000ppm,
- a P-content comprised between 0 and 800ppm,
- a B-content comprised between 0 and 20ppm,
- a Si-content comprised between 0 and 4000ppm,
- a Mn-content comprised between 500 and 7000ppm,
- a S-content comprised between 0 and 200ppm, preferably comprised between 0 and 100ppm,
- the balance being substantially Fe and incidental impurities.

[0017] For a steel composition intended for galvanising, the preferable carbon-content is comprised between 20ppm and 25ppm.

[0018] For a steel composition intended for galvannealing, the preferable carbon-content is comprised between 25ppm and 30ppm.

[0019] The present invention further relates to a process for producing an ultra-low carbon bake hardenable, galvanised or galvannealed steel product comprising the steps of,

- preparing a composition wherein the titanium content is comprised between 3.42N and 3.42N + 60ppm, and the niobium content is comprised between 50 ppm and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur during the process,

- if necessary, reheating said slab at a temperature (T1) higher than 1000°C,

- performing a hot rolling having a finishing temperature (T2) higher than A_{r3}-100°C and preferably higher than A_{r3}-50°C,

- performing a coiling at a temperature comprised between 500°C and 750°C,
- performing a cold rolling in order to obtain a reduction higher than 60%,
- annealing up to a maximum soaking temperature comprised between 780°C and 880°C,
- performing a galvanising or galvannealing step
- performing a skinpass reduction comprised between 0.4% and 2%.

[0020] Reheating of the slab can be unnecessary if the casting is followed in line by the hot rolling facilities.

[0021] During the process, no substantial formation of TiC and NbC occurs, which is why a lower soaking temperature can be applied. Also, the use of Ti to bind the N is advantageous in that it solves the problem of high coiling temperatures.

[0022] Furthermore, the Nb-content is independent of the C-content, which solves the problem of the fixed Nb/C relation.

[0023] The presence of Nb ensures that the conventional yield strength $Re_{0.2}$ at the zinc bath temperature (typically 460°C), of the steel sheet obtained by the process of the present invention, is minimum 130MPa. At 460°C, microplasticity, for the steel obtained by the process of the present invention, starts at a stress level equal or above 70MPa, which is a higher value than that of steels without Nb. Meanwhile, the yield strength at room temperature does not differ from the values obtained on these compared steels (having no Nb), which are typically ranging from 160MPa to 350MPa after processing and temper rolling. This solves the problem of plastic deformation during processing in the zinc bath

[0024] Bake hardening values obtained on the final product are as follows :

Guaranteed BH_0 en BH_2 measured for a thickness lower than Imm, in the as skinpassed condition (measured according to the standard SEW094):
GI (galvanised):

$$BH_o > 35MPa, \text{ and } >40MPa \text{ at } C>20ppm$$

$$BH_2 > 40 \text{ MPa}$$

GA (galvannealed) :

$$BH_0 > 20MPa$$

$$BH_2 > 30MPa$$

[0025] The final product also exhibits an excellent dent resistance and a superior surface quality after stamping and painting, as a consequence of the absence of said plastic deformations occurring around the zinc bath section.

Brief description of the drawings

[0026] Fig. 1 is describing the dent resistance of a steel according to the present invention.

[0027] Fig. 2a is describing hot tensile test results at a temperature of 460°C

[0028] Fig. 2b is describing hot tensile test results at a temperature of 480°C

Detailed description of the preferred embodiments

[0029] According to the present invention an ultra-low carbon bake hardenable galvanised or galvannealed steel product is proposed, having a composition comprising :

- C : between 15ppm and 45ppm, preferably between 20ppm and 30ppm : the C-content is important to acquire a balance between bake hardening and ageing characteristics of the steel. All of the carbon is supposed to remain

in a 'free' condition, as opposed to bound in carbide form, to accommodate the paint baking. The minimum C-content guarantees the bake hardening, the maximum reduces the risk of stretcher strains.

- N : maximum 100ppm. The maximum is imposed because the N-content is related to the Ti-content. The N-content is preferably lower than 40ppm because of a better formability due to a lower amount of precipitates.
- Ti : between 3.42 times the N-content and 3.42XN + 60ppm. A minimum Ti-content is needed to bind all of the N, the maximum allowable level is needed to avoid formation of $Ti_xC_yN_z$. In this respect, preferably 3.42N+30ppm should be used as maximum level when the upper C-levels of the above C-range are used. The use of Ti to bind the N is an improvement compared to existing steels in which Al is used for this purpose. The use of Al for binding N in case of continuously annealed steel requires higher coiling temperatures in order to prevent deterioration of mechanical and ageing properties at the coil ends. These higher coiling temperatures are negative for the pickling. Also, the presence of unbound N is particularly detrimental for the resistance of the bake hardening quality to ageing. The use of Ti ensures the absence of free N more than does the use of Al. Accordingly, Ti is not added as function of S. No TiS or $Ti_4C_2S_2$ are observed in the steel of the present invention.
- Nb : between 50ppm and 100ppm. The minimum is required to ensure the finer grain size and to acquire a higher yield strength at the zinc bath temperature (typically 460°C). The maximum level should not be exceeded in order to avoid the formation of NbC. It should be noted that the Nb addition is in a fixed range, independent of C and carbonitride formation does not have to be controlled since no significant amounts of NbC or TiC are formed in the preferential analysis.
- Al : maximum1000ppm. Used for de-oxidising. The maximum level is introduced to avoid inclusions.
- P : maximum 800ppm. P is added for strengthening purposes, but the amount must be controlled in order to avoid lowering the galvannealing speed.
- B : maximum20ppm. The presence of B is not a necessity, but it can be added to improve the Cold Working Embrittlement properties. The maximum is introduced to avoid the formation of BN, which may leave some Ti unbound, which in turns can lead to a loss of unbound C.
- Si : maximum 4000ppm. Si is also added for strengthening purposes, which improves the texture in the presence of P and Mn and which opposes the low temperature ageing. The maximum is introduced in order to avoid a deterioration of the surface treatability.
- Mn : between 500 and 7000ppm, and added for strengthening purposes. It also bounds S as MnS. The maximum is introduced to improve texture and drawability.
- S : maximum 200ppm, preferably lower than 100ppm. It should be noted that a minimum S-content is not necessary here.
- the balance being substantially Fe and incidental impurities,

[0030] Also according to the present invention, said steel product is produced by a method comprising the steps of :

- preparing a slab having a composition such as defined here above,
- if necessary, reheating said slab at a temperature T1, higher than 1000°C,
- hot rolling mill finishing at a temperature T2, higher than A_{r3}-100°C, preferably higher than A_{r3}-50°C (There is no need in the present invention to perform hot rolling strictly above Ar3),
- Hot rolling mill coiling at a temperature between 500°C and 750°C,
- Cold rolling and obtaining a reduction, higher than 60%,
- annealing up to a maximum soaking temperature comprised between 780°C and 880°C,
- performing a galvanising or galvannealing step
- performing a skinpass reduction comprised between 0.4% and 2%

[0031] An overageing treatment can be applied in the course of the annealing line after the soaking or after the coating step, but this results in a slight loss of bake hardening. Preferably, an overageing should not be applied.

[0032] The addition of P, Mn and Si leads to yield strengths between 160MPa and 350MPa at room temperature. Research relative to the present invention has indicated that P, Mn and Si have no significant influence on the bake hardening of ULC BH steels, in so far as their amounts are lying within the proposed boundaries.

[0033] Figure 1 proves the excellent dent resistance of the steel, by comparing the ULC BH 220 GA (standard SEW094) variety to the variety DC04 (standard EN 10130) having good drawing properties and a yield strength of 165MPa. The data in the graph are based on a Marciniak panel with a thickness normalised to 0.711mm and baked after 0 or 4% biaxial deformation. It is apparent from figure 1 that the necessary force to obtain a permanent dent of 0.1mm has doubled.

[0034] Because of the insufficient appearance of the surface of steels obtained by the Ti-ULC route for their use in exposed applications, a small amount of Nb was added here, in order to acquire a finer grain size and increase the grain boundary strength at the temperature of the zinc bath. There is no need here to form NbC and subsequently

dissolve it during recristallisation annealing (as is described in EP A 0064552). In the present invention, there is no substantial precipitation of niobium carbides, for example on the castings 1 and 2 of the preferred embodiment, whose composition is described in table 1. On these castings, a quantitative TEM survey revealed that a maximum of 0.2ppm of carbon was bound in the form of $Nb_{0.7}Ti_{0.3}C(N)$ in a coil of GI-steel, or $Nb_{0.4}Ti_{0.6}C$, in a coil of GA-steel. These results clearly prove the fact that the small Nb-content does not lead to substantial precipitation of carbides.

[0035] Earlier high temperature tensile tests have revealed that the tensions which cause the initial plastic deformation of Ti-ULC 180 BH steel during the tensile test at 460°C are of the same order of magnitude as the tensions imposed on the Ti-ULC 180 BH steel during its passing through the zinc bath. The idea arose therefore, to use the Nb-addition as a means of increasing the yield strength around this temperature of 460°C.

[0036] Figures 2a and 2b show the results of tensile tests performed at 460°C-480°C on Ti-ULC (state of the art reference quality) and on Ti-Nb ULC 180 BH, a steel according to the present invention. Measurements are performed according to the standard EN 10002.

[0037] The plastic deformation of the Ti-ULC steel is started at a lower tension and the conventional yield strength $Re_{0.2}$ is lower by 20-30MPa. These results prove the ability of a small addition of Nb to increase the yield strength at the zinc bath temperature, while maintaining the same yield strength at room temperature. Figures 2a and 2b equally show that microplastic deformation at 460-480°C occurred starting from 70-90MPa for the steel according to the invention, as opposed to ±50MPa in the case of the reference quality Ti-ULC steel. The start of microplasticity is defined as the first deviation from the linear part of the stress strain diagram. In some tensile tests the microplasticity start of the Ti-ULC quality was found to be as low as 40MPa at 460-480 degrees. This proves that the Nb does provide the desired effect. Apparently, the sum of the tensile stresses mentioned above is in practical industrial hot dip galvanising/galvannealing coating lines frequently situated above the microplasticity level of the steel of comparison but below the microplasticity level of the steel of invention

[0038] As expected, the Nb-addition also led to a finer grain size : the average grain diameter was 13μm, as opposed to 18μm for the Ti-ULC steel, both steels being subjected to the same soaking temperature (±830°C) while the Ti-Nb ULC underwent a lower cold reduction : 69% as opposed to 75% for the Ti-ULC steel.
Due to the Nb-addition, the paint appearance of the 180 BH steel was evaluated as very good.

[0039] The following bake hardening values for the final product obtained by the process of production described here above are as follows :
Guaranteed BH_0 en BH_2 measured for a thickness lower than lmm (measured according to the standard SEW094):

$$\text{GI: } BH_o > 35\text{MPa, and } >40\text{MPa at } C>20\text{ppm}$$

$$BH_2 > 40\text{MPa}$$

$$\text{GA: } BH_0 > 20\text{MPa}$$

$$BH_2 > 30\text{MPa}$$

Best mode embodiment

[0040] Table 1 shows the composition of two castings of ULC BH (Ti-Nb) steel products according to the present invention.

[0041] The processing steps are :

- Slab reheating at T1 > 1250°C
- Hot rolling mill finishing at T2, between 910°C and 940°C
- Hot rolling mill coiling at T3 : between 700°C and 750°C
- Cold reduction : 69%
- Hot dip galvanising line soaking at temperature : between 829°C and 880°C
- Skinpass : 1-1.32%

[0042] Table 2 shows the obtained mechanical properties of the Ti-Nb ULC BH steel grades.

[0043] Table 3 gives an overview of the bake hardening and paint appearance properties of the (Ti-Nb) ULC BH steel according to the present invention, compared to the corresponding properties of a reference Ti-ULC BH steel. It should

be stressed that the paint appearance is judged on samples acquired on the industrial line, and not in the laboratory.

Table 1:

composition (ppm) of the Ti-Nb steel products according to the present invention.											
Cast	C	N	S	Ti	Nb	P	Mn	Si	Al	B	V
1	25-36	22	74	80	80	140	1580	1230	350	1	20
2	17-27	26	49	90	70	180	1570	1180	360	1	20

Table 2:

Mechanical properties of the Ti-Nb ULC BH steel before stamping and painting (transversal, aged 1h at 100°C, thickness 0.75mm).									
Cast N°	**Grade**	**R_e** MPa	**R_m** MPa	**A80** %	**YPE** %	**r90**	**n90**	**BH_0** MPa	**BH_2** MPa
1	GI	220-242	331-346	35-41	0-1.0	1.82-2.32	0.173-0.186	42-60	42-52
1	GA	227-252	328-345	31-46	0-1.0	1.67-1.90	0.159-0.190	26-45	30-50
2	GI	202-217	322-332	35-42	0-0.5	1.86-2.37	0.181-0.201	37-47	45-48
2	GA	214-229	318-330	32-37	0	1.63-1.93	0.164-0.188	21-40	32-38

Table 3:

Summary : results of Bake Hardening derived from tensile test results according to SEW094 and paint appearance of stamped and painted samples, based on painted Marciniak samples.				
Grade GI (galvanised)				
Line		Reference steel: Ti-ULC	Reference steel: Ti-ULC	Invention steel : Ti-Nb ULC
		C: 12-18 ppm	C: 41-47 ppm	C: 17-26 ppm
Line 1	BH_0	5		
	BH_2	26		
	Paint appearance	**Bad**		
Line 2	BH_0	20		37-47
	BH_2	34		45-48
	Paint appearance	**Bad**		**Good**
Line 3	BH_0		18-42	
	BH_2		43-60	
	Paint appearance		**Bad**	

GA (galvannealed)				
Line		Reference steel: Ti-ULC	Reference steel: Ti-ULC	Invention steel : Ti-Nb ULC
		C: 12-18 ppm;	C: 41-47 ppm	C: 22-27 ppm
Line 1	BH_0	2		
	BH_2	19		
	Paint appearance	**Bad**		

(continued)

GA (galvannealed)				
Line		Reference steel: Ti-ULC	Reference steel: Ti-ULC	Invention steel : Ti-Nb ULC
		C: 12-18 ppm;	C: 41-47 ppm	C: 22-27 ppm
Line 2	BH_0	1		21-40
	BH_2	22		32-38
	Paint appearance	**Bad**		**Good**
Line 1 with overageing Line 2 without overageing Line 3 without overageing				

Claims

1. Ultra-low carbon steel composition, intended to be used to produce a steel product in a process comprising the steps from hot-rolling until hot-dip galvanising or galvannealing and skinpass, said composition being characterised by the titanium content, comprised between 3.42N and 3.42N + 60 ppm for a fixed nitrogen content (N) and by the niobium content, comprised between 50 ppm and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur during said process.

2. Ultra-low carbon steel composition according to claim 1, wherein no more than 2ppm of carbon is bound in the form of niobium carbides during said process.

3. Ultra-low carbon steel composition according to claim 1 characterised by :

   - a C-content comprised between 15ppm and 45ppm,
   - a N-content comprised between 0 and 100ppm, preferably between 0 and 40ppm,
   - an Al-content comprised between 0 and 1000ppm,
   - a P-content comprised between 0 and 800ppm,
   - a B-content comprised between 0 and 20ppm,
   - a Si-content comprised between 0 and 4000ppm,
   - a Mn-content comprised between 500 and 7000ppm,
   - a S-content comprised between 0 and 200ppm, preferably comprised between 0 and 100ppm,
   - the balance being substantially Fe and incidental impurities.

4. Ultra-low carbon steel composition according to claim 3 characterised by a the C-content, comprised between 20ppm and 25ppm.

5. Ultra-low carbon steel composition according to claim 3 characterised by the C-content, comprised between 25ppm and 30ppm.

6. A process for producing an ultra-low carbon bake hardenable, galvanised or galvannealed steel product comprising the steps of :

   - preparing a steel slab having a composition, wherein the titanium content is comprised between 3.42N and 3.42N + 60ppm for a fixed N-content (N), and the niobium content is comprised between 50 ppm and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur during the process,
   - performing a hot rolling having a finishing temperature (T2) higher than A_{r3}-100°C and preferably higher than A_{r3}-50°C,
   - performing a coiling at a temperature comprised between 500°C and 750°C,
   - performing a cold rolling in order to obtain a reduction higher than 60%,
   - annealing up to a maximum soaking temperature comprised between 780°C and 880°C,
   - performing a galvanising or galvannealing step,

- performing a skinpass reduction comprised between 0.4% and 2%.

7. A process according to claim 6, wherein a step of reheating said slab at a temperature (T1) higher than 1000°C is performed before performing the hot rolling step.

8. Ultra-low carbon bake hardenable galvanised steel product, produced in a process comprising the steps from hot rolling until hot-dip galvanising or galvannealing and skinpass, said product having a composition wherein the titanium content is comprised between 3.42N and 3.42N+60 ppm for a fixed N-content (N) and the niobium content is comprised between 50 and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur and the yield strength $Re_{0.2}$ at 460°C is at least 130MPa, the start of microplasticity at 460°C occurring above a stress level of 70MPa, while the final yield strength $Re_{0.2}$ at room temperature is comprised between 160MPa and 350MPa, after processing and skinpass.

9. An ultra-low carbon bake hardenable galvanised steel product according to claim 8 wherein the bake hardening BH_0 is higher than 35MPa and BH_2 is higher than 40 MPa, for a thickness lower than 1 mm in the as skinpassed condition.

10. Ultra-low carbon bake hardenable galvannealed steel product having a composition wherein the titanium content is comprised between 3.42N and 3.42N+60 ppm for a fixed N-content (N) and the niobium content is comprised between 50 and 100 ppm, these contents being fixed so that no substantial precipitation of niobium carbides will occur and the yield strength $Re_{0.2}$ at 460°C is at least 130MPa, the start of microplasticity at 460°C occurring above a stress level of 70MPa, while the final yield strength $Re_{0.2}$ at room temperature is comprised between 160MPa and 350MPa, after processing and skinpass.

11. Ultra-low carbon bake hardenable galvannealed steel product according to claim 10 wherein the bake hardening BH_0 is higher than 20MPa and BH_2 is higher than 30MPa, for a thickness lower than 1 mm in the as skinpassed condition.

12. Use of the steel product according to claims 8 and 10 to confer a superior paint appearance to exposed parts.

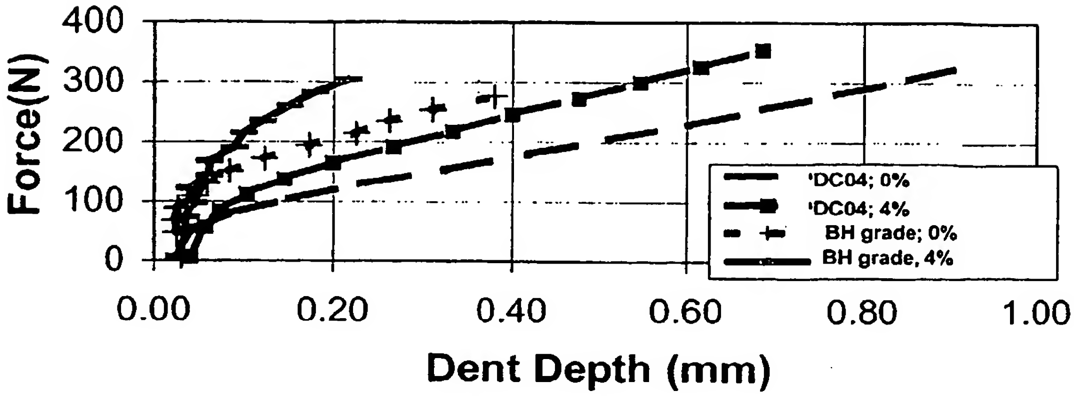
400
300
200
100
0
Force(N)
0.00
0.20
0.40
0.60
0.80
1.00
Dent Depth (mm)
DC04; 0%
DC04; 4%
BH grade; 0%
BH grade, 4%

Figure 1

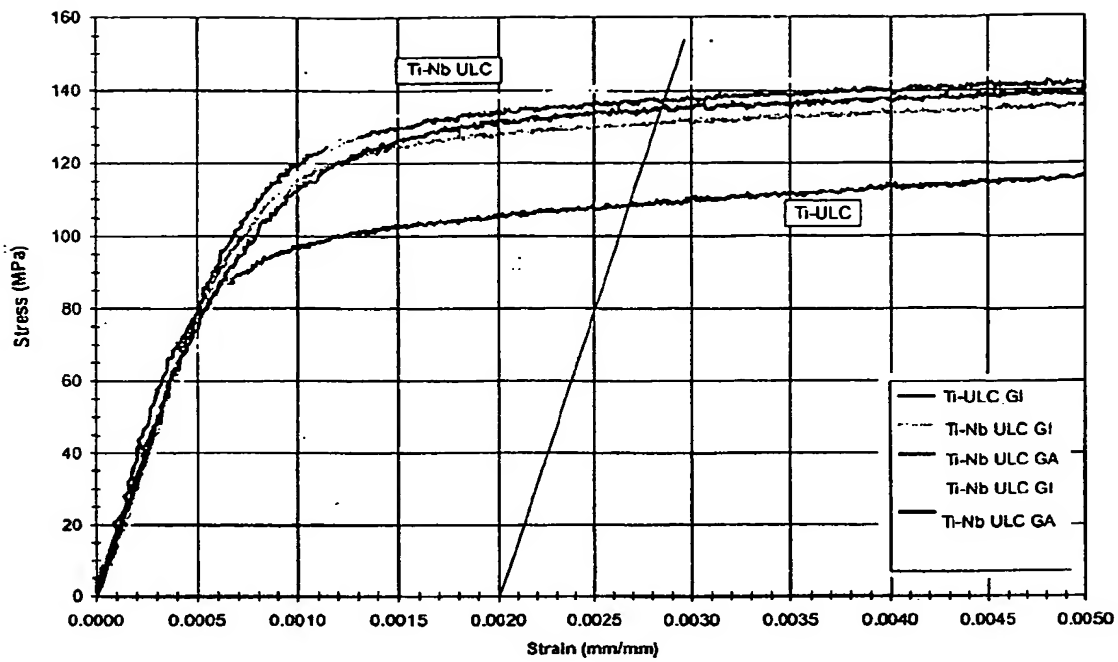

Figure 2a

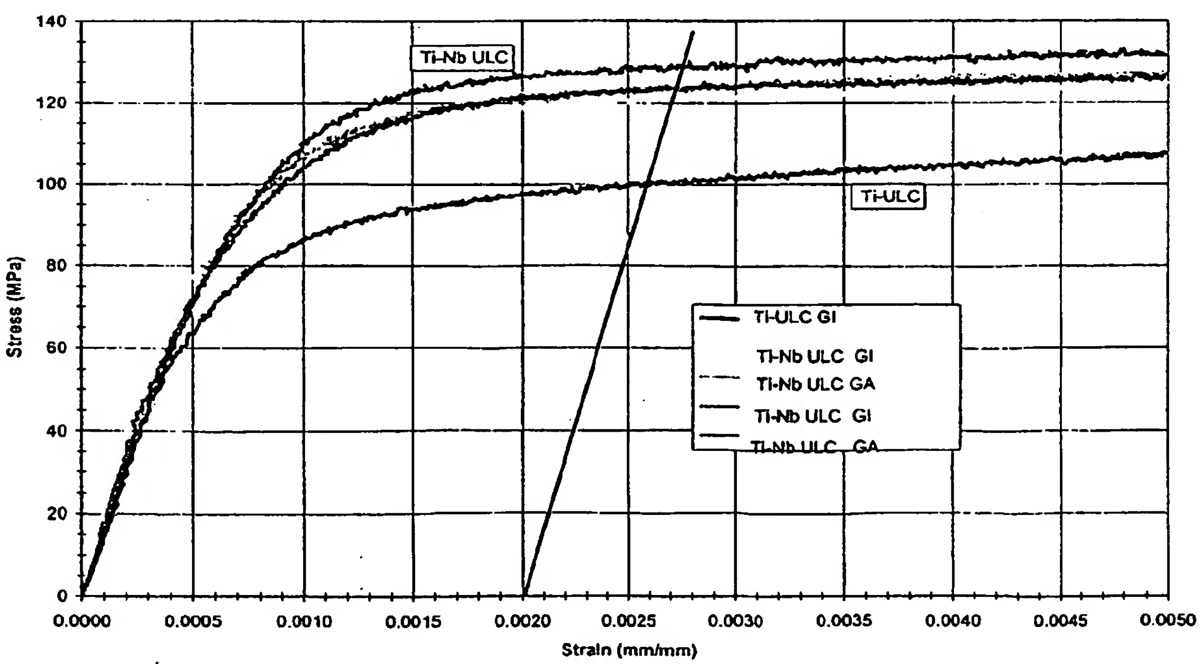

Figure 2b

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 99 87 0278

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	PATENT ABSTRACTS OF JAPAN vol. 018, no. 040 (C-1155), 21 January 1994 (1994-01-21) -& JP 05 263185 A (NIPPON STEEL CORP), 12 October 1993 (1993-10-12)	1-5,8-11	C22C38/12 C22C38/14
Y	* abstract; examples 3-3,3-1 *	6,7	
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 295 (C-0957), 30 June 1992 (1992-06-30) -& JP 04 080323 A (SUMITOMO METAL IND LTD), 13 March 1992 (1992-03-13) * abstract; example 8 *	1-3	
Y	DATABASE WPI Section Ch, Week 199321 Derwent Publications Ltd., London, GB; Class M24, AN 1993-172875 XP002144186 -& JP 05 105985 A (SUMITOMO METAL IND LTD), 27 April 1993 (1993-04-27) * abstract *	6,7	
A	PATENT ABSTRACTS OF JAPAN vol. 1996, no. 04, 30 April 1996 (1996-04-30) -& JP 07 316733 A (KAWASAKI STEEL CORP), 5 December 1995 (1995-12-05) * abstract *		TECHNICAL FIELDS SEARCHED (Int.Cl.7) C22C
A	PATENT ABSTRACTS OF JAPAN vol. 1998, no. 10, 31 August 1998 (1998-08-31) -& JP 10 121192 A (SUMITOMO METAL IND LTD), 12 May 1998 (1998-05-12) * abstract *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	3 August 2000	Ashley, G

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 99 87 0278

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

03-08-2000

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 05263185 A	12-10-1993	NONE	
JP 04080323 A	13-03-1992	NONE	
JP 5105985 A	27-04-1993	NONE	
JP 07316733 A	05-12-1995	NONE	
JP 10121192 A	12-05-1998	NONE	

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82